Using instantaneous radiative measurements to assess cloud properties

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Outlook

- Determining the instantaneous cloud reflectance and cover over tropical ocean
- Analysis of the cloud reflectance and cloud cover for low-level tropical marine clouds in observations and in models
- Random sampling and sub-sampling

Cloud reflectance over ocean

On a 2°x2° grid, over the tropical ocean, the cloud reflectance **CR** is deduced from the

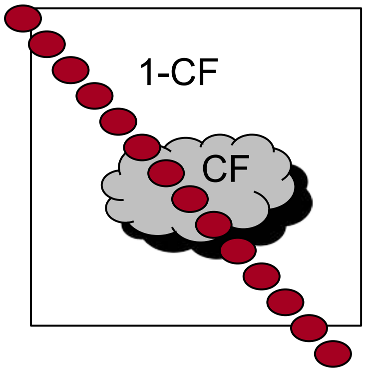
cloud cover CC (Calipso)

total reflectance R (Parasol)

clear sky reflectance CSR

$$R = CC * CR + (1 - CC) * CSR$$

$$CR = [\, R - (1 - CC) * CSR \,] / CC$$



2°x2°
or model
grid box

Data are available only on a very small fraction of the grid box

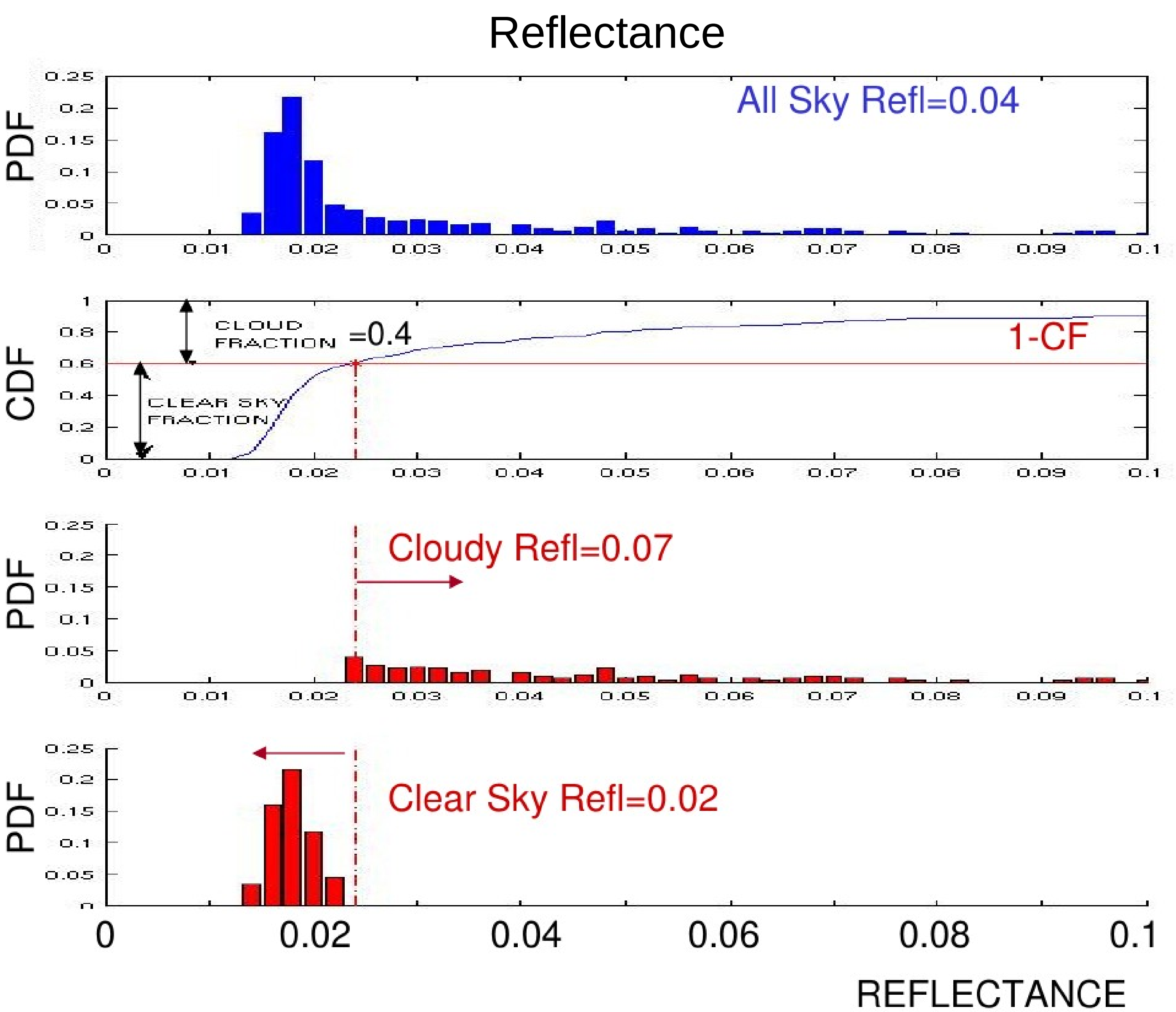
PARASOL reflectance below CALIPSO trace

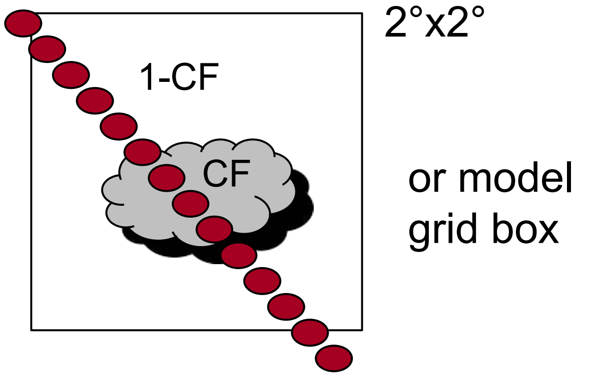
To facilitate the link between cloud reflectance and cloud optical thickness, we only consider PARASOL reflectance with

- a viewing zenith angle $\theta v = 27° \pm 2.5°$
- a (solar - viewing) azimuth angles $\varphi s - \varphi v = 320° \pm 2.5°$

[Konsta et al., 2016]

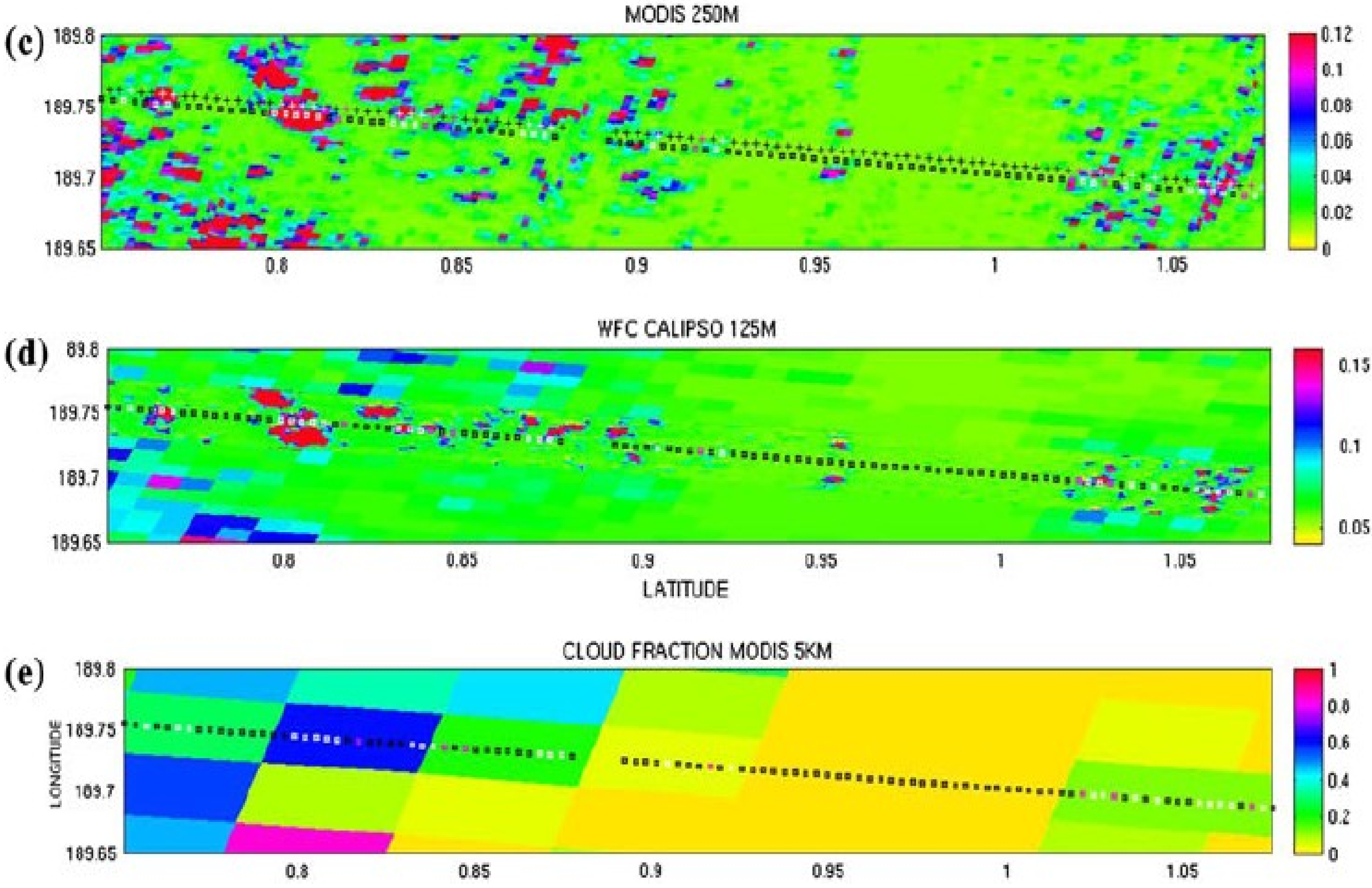
Determining the cloud reflectance on a 2°x2° grid





PARASOL reflectance below CALIPSO trace

Determining the cloud reflectance on a 2°x2° grid



[Konsta et al., 2012]

Cloud cover and cloud reflectance over ocean

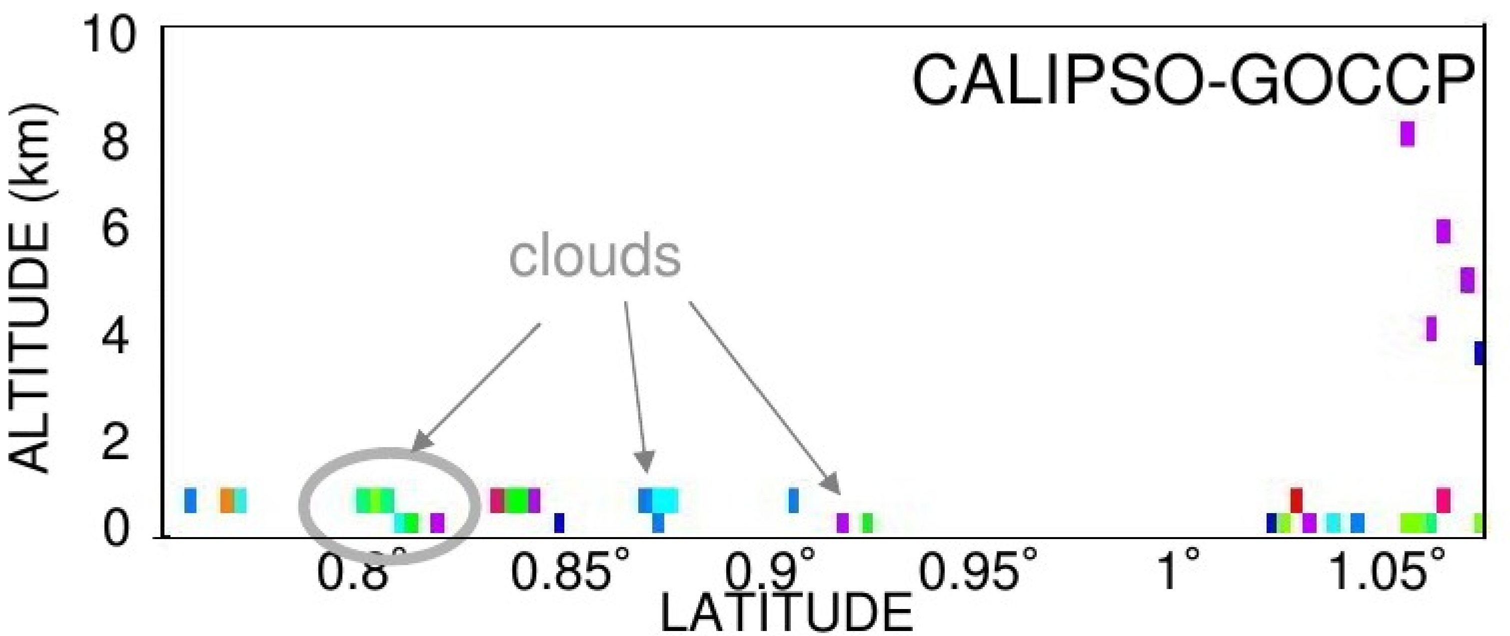
On a 2°x2° grid, over the tropical ocean, the cloud reflectance **CR** is deduced from the cloud cover **CC** and total reflectance **R**, knowing the clear sky reflectance **CSR** :

$$R = CC * CR + (1 - CC) * CSR$$

$$CR= [R – (1 - CC) * CSR] / CC$$

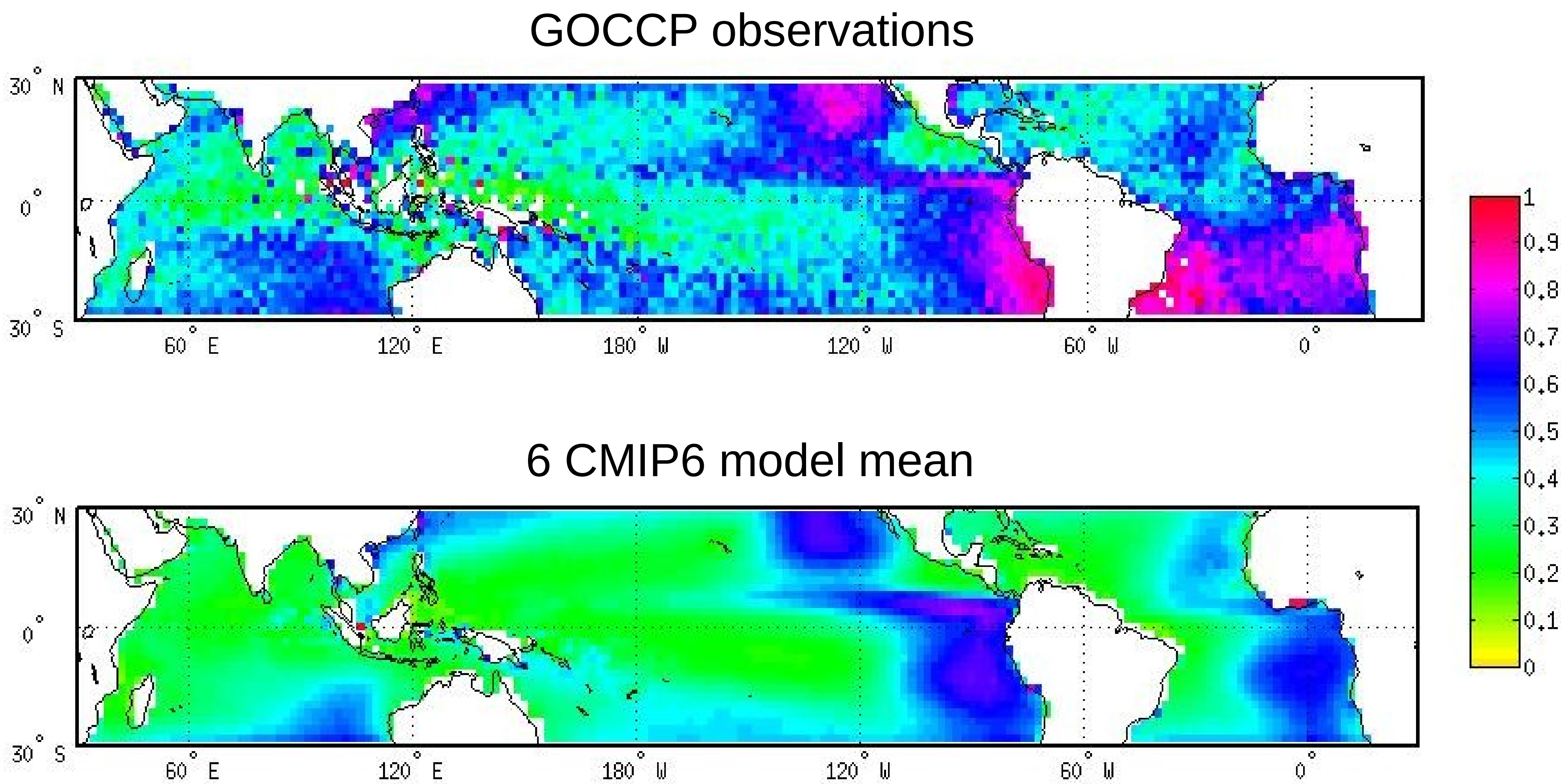
Scenes where low level clouds dominate

CClow > 0.9 CC



Cloud cover

When low level clouds are dominant, 2007-2010

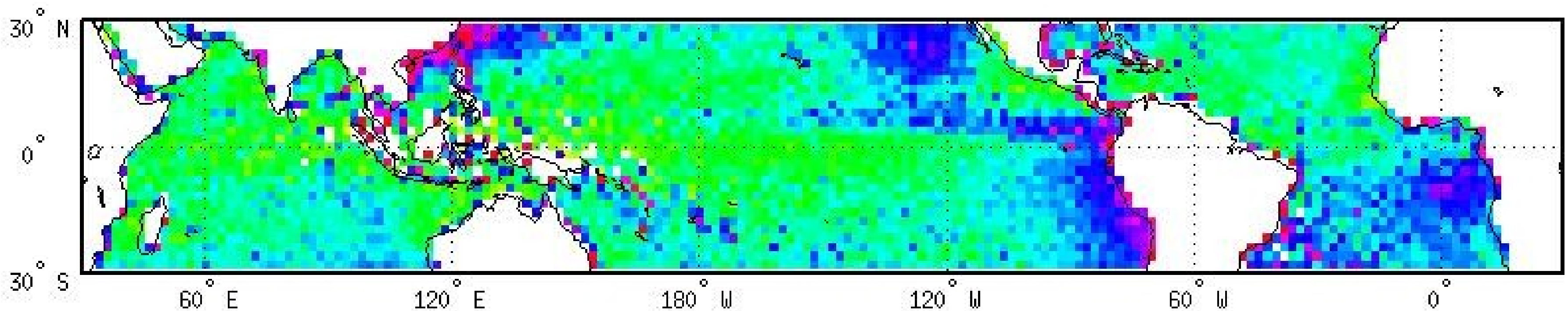


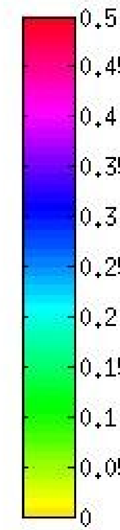
[Konsta et al., GRL, 2022]

Cloud Reflectance

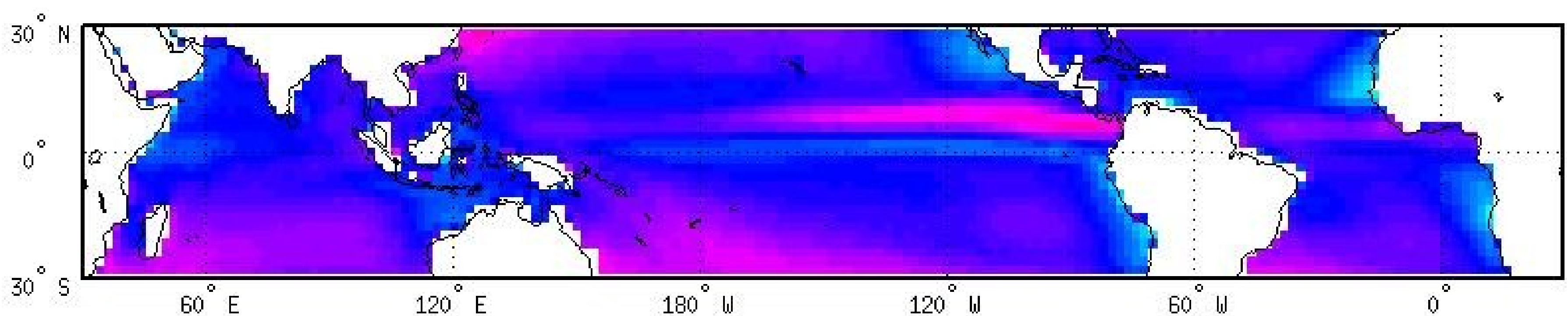
When low level clouds are dominant, 2007-2010

PARASOL observations



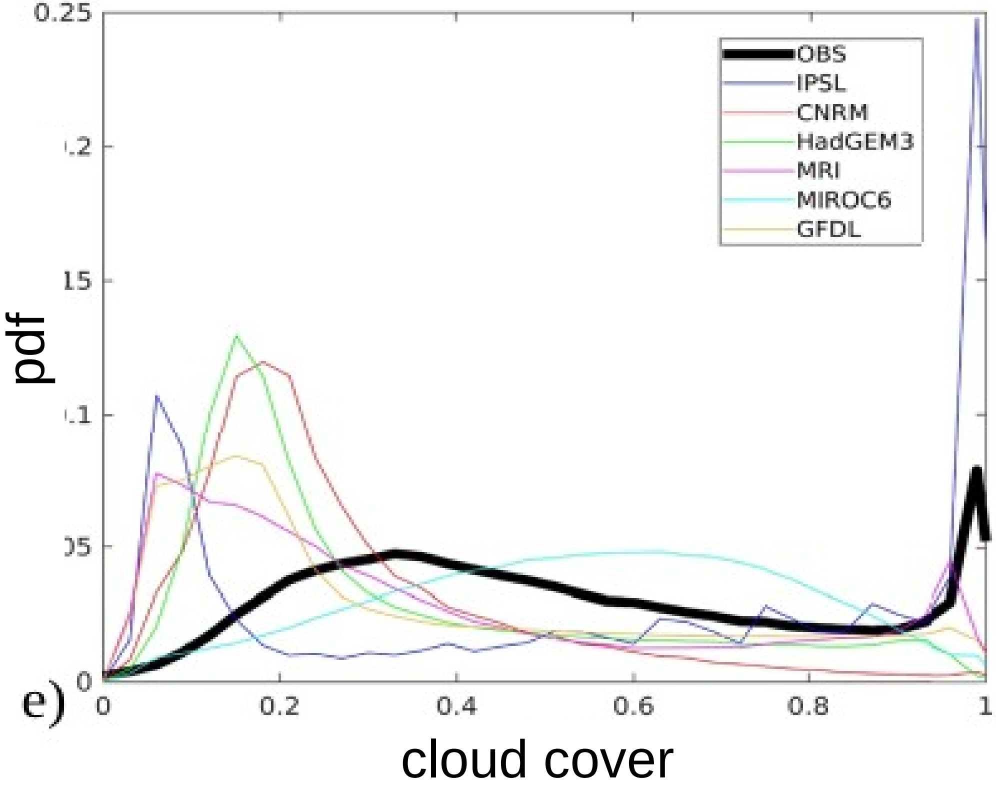


6 CMIP6 model mean

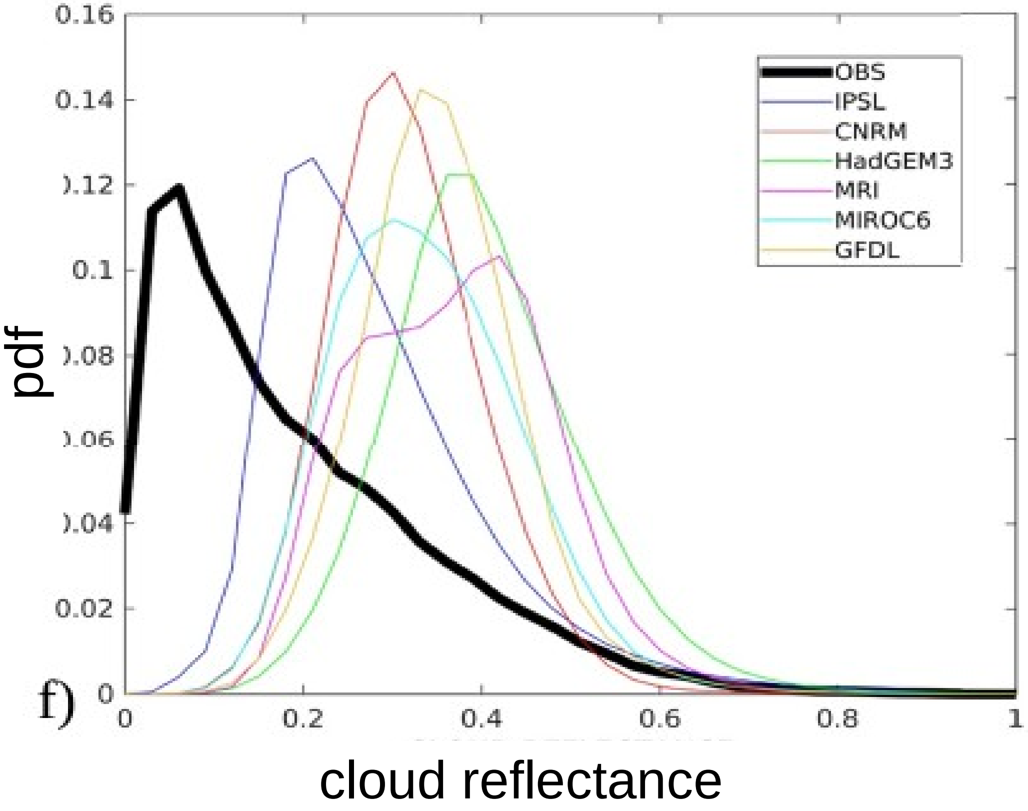


[Konsta et al., GRL, 2022]

Cloud cover

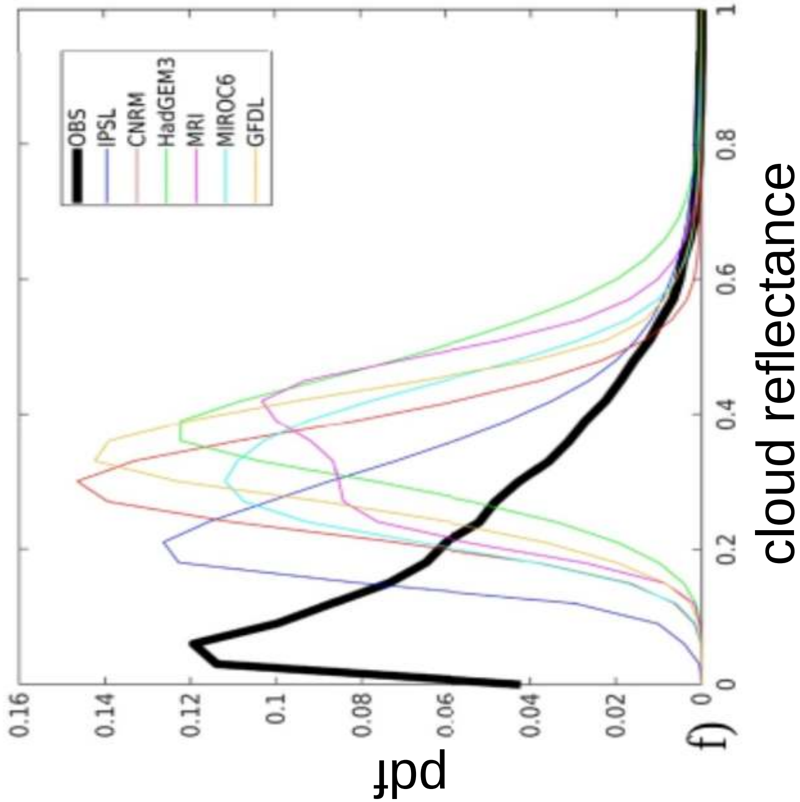


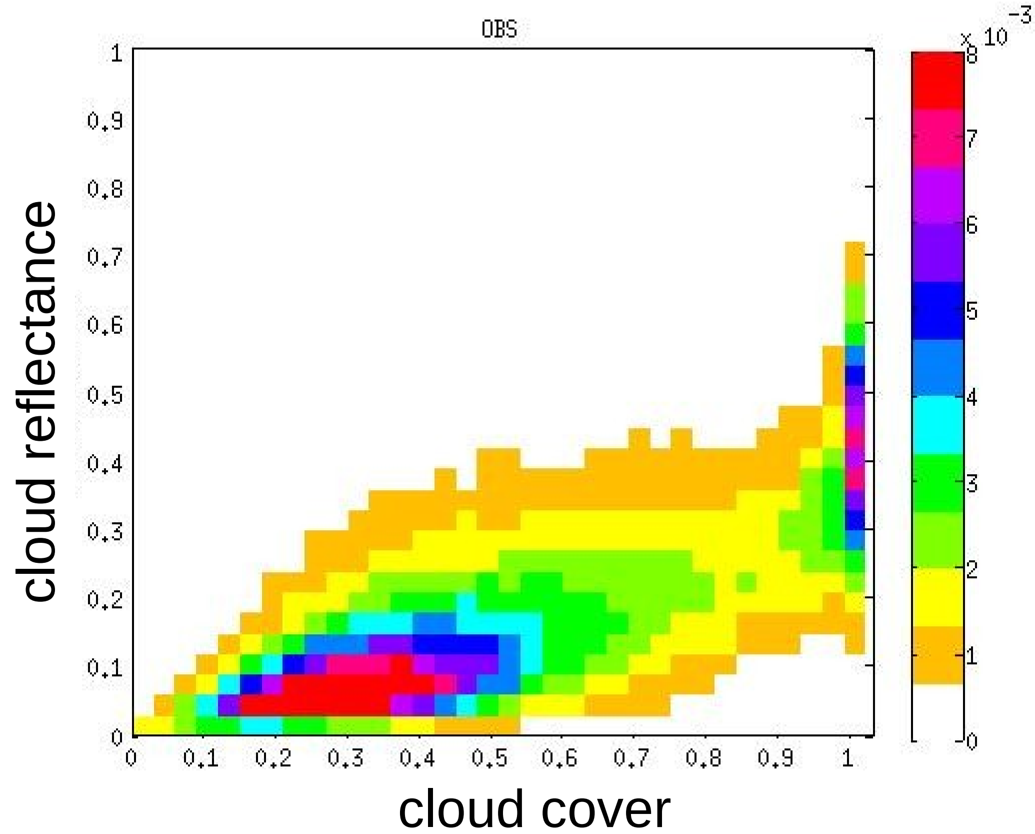
Cloud Reflectance

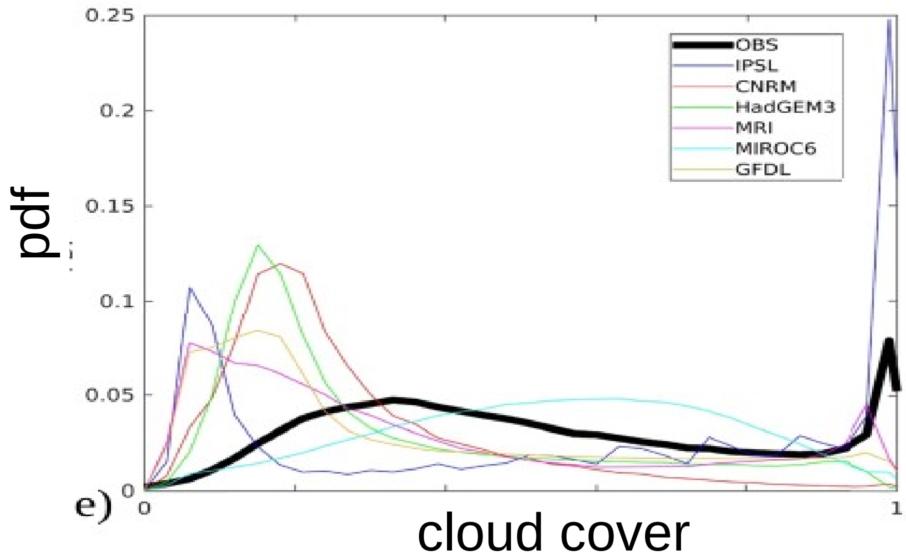


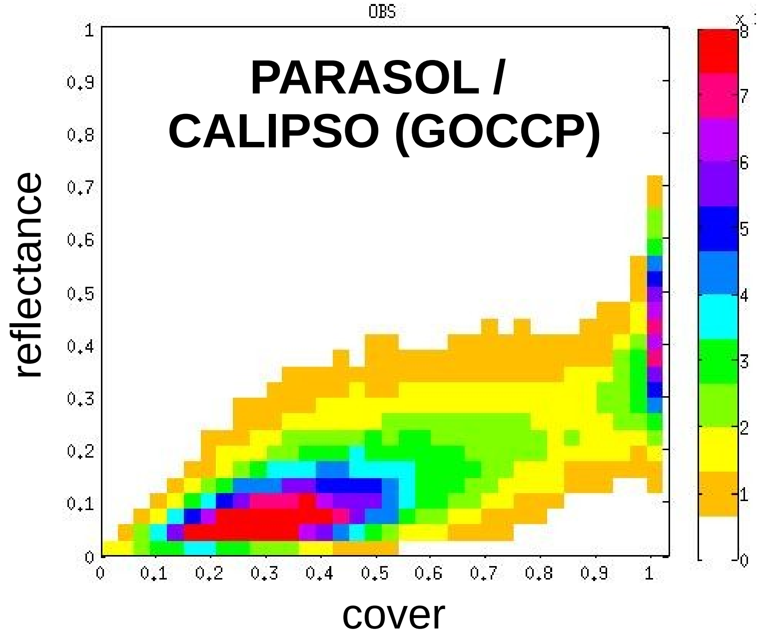
[Konsta et al., GRL, 2022]

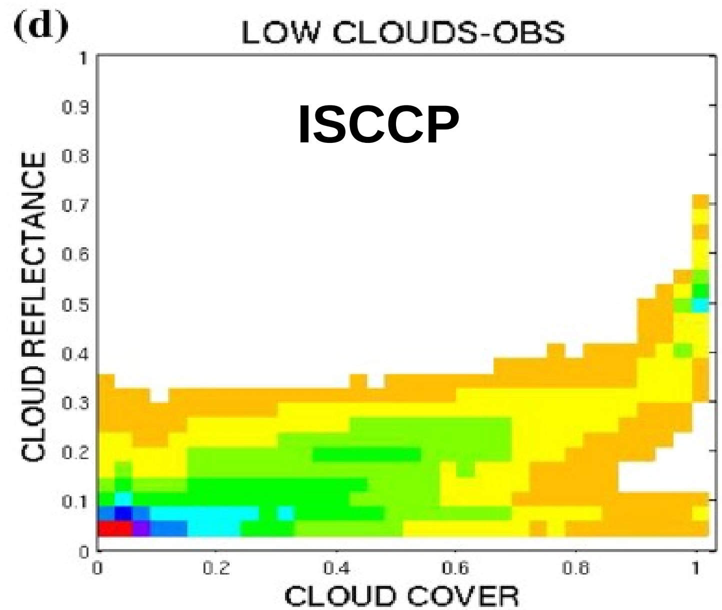
Cloud reflectance versus cloud cover



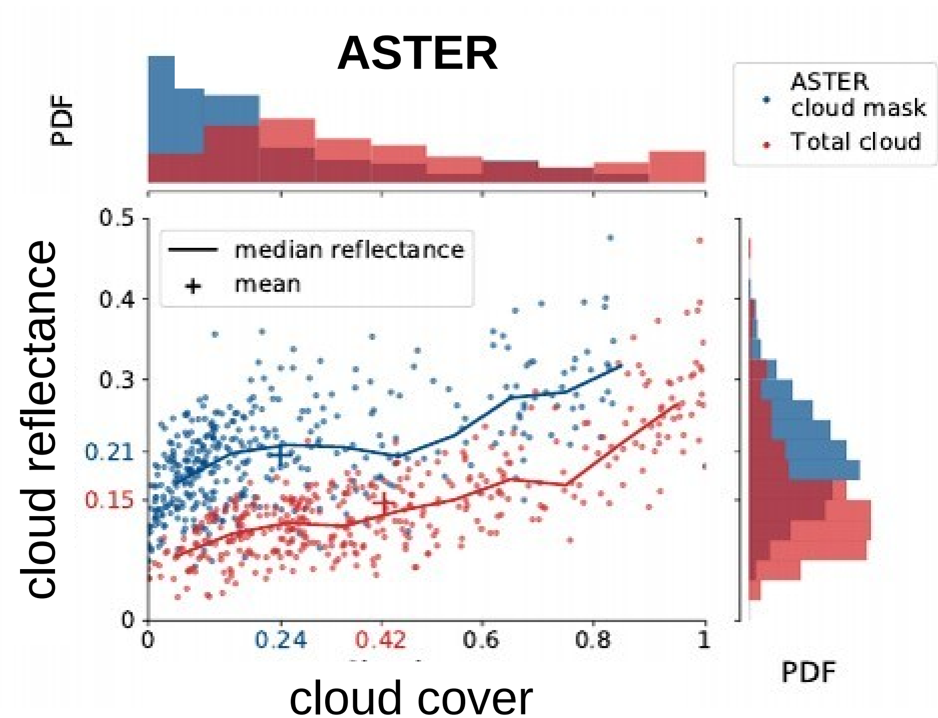




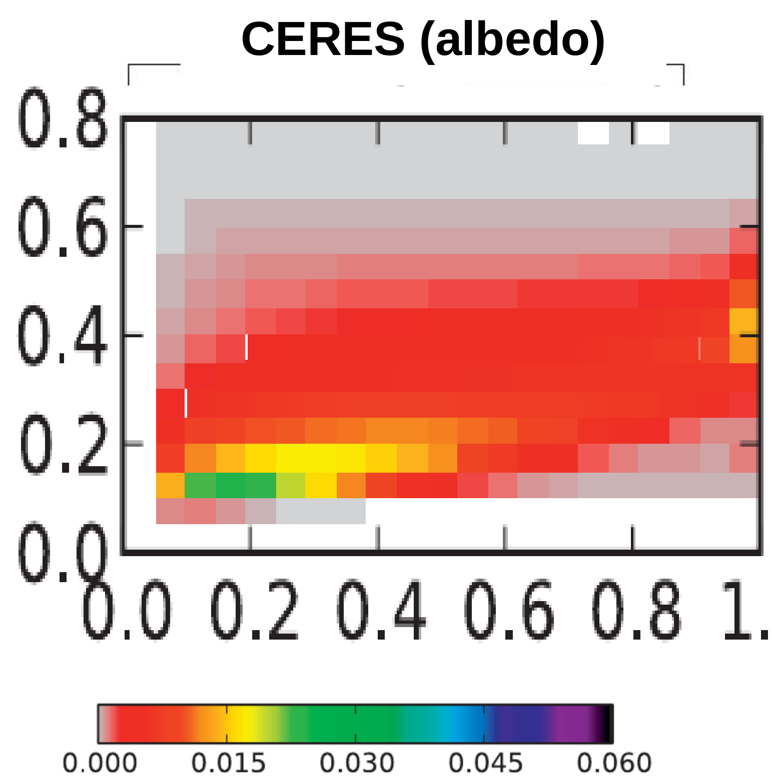




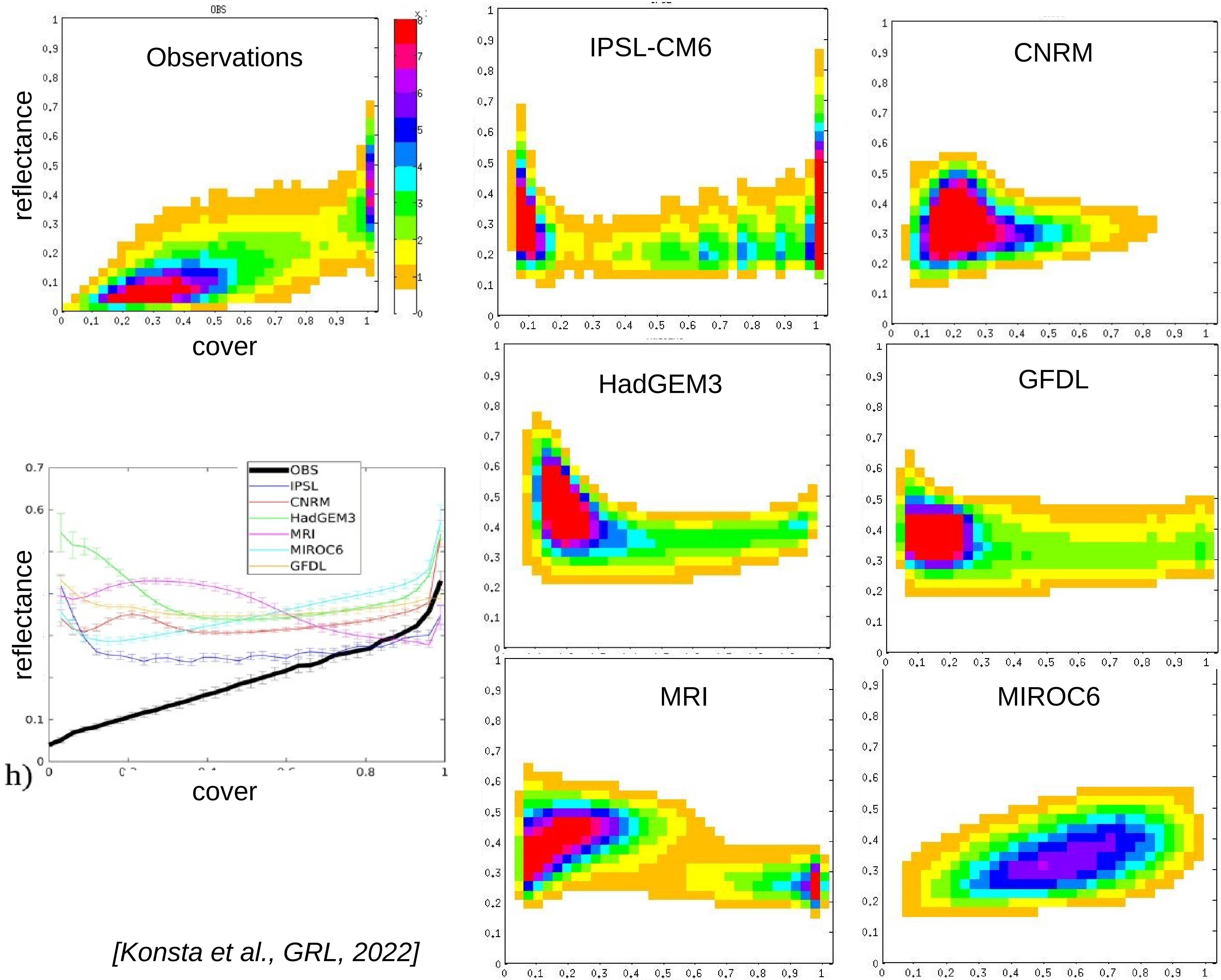
[Konsta et al., CDYN, 2016]



[Mieslinger et al., ACP, 2022]



[Cole et al. 2011]

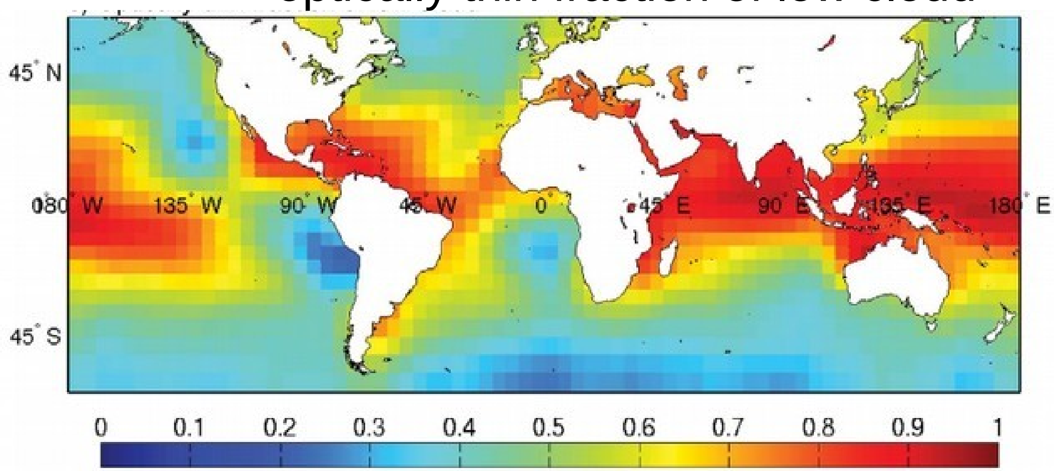


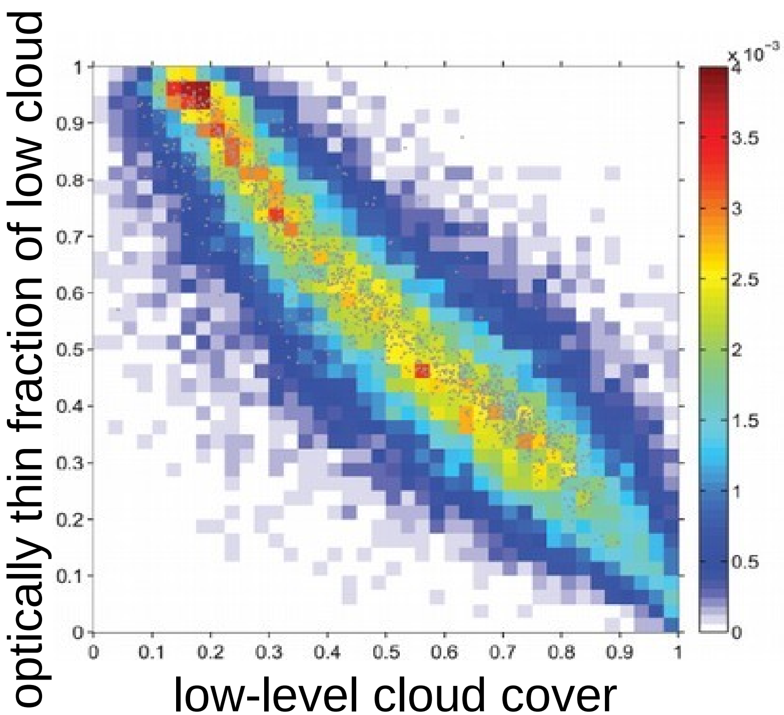
[Konsta et al., GRL, 2022]

Importance of ***optically thin low-level clouds*** over oceans

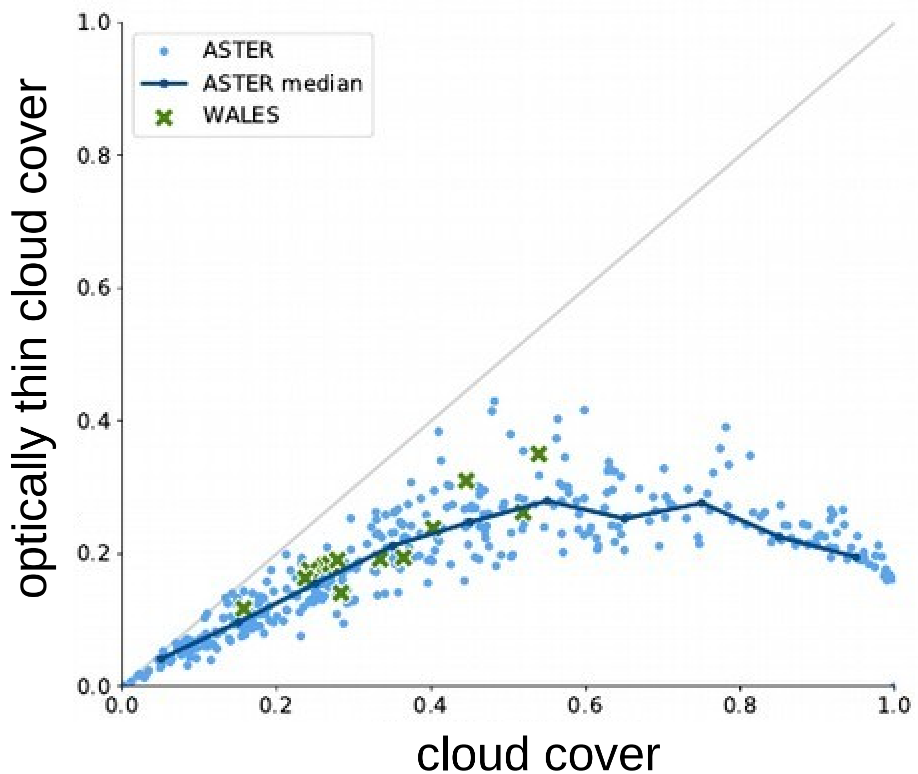
From **Calipso** night measurements

optically thin fraction of low cloud



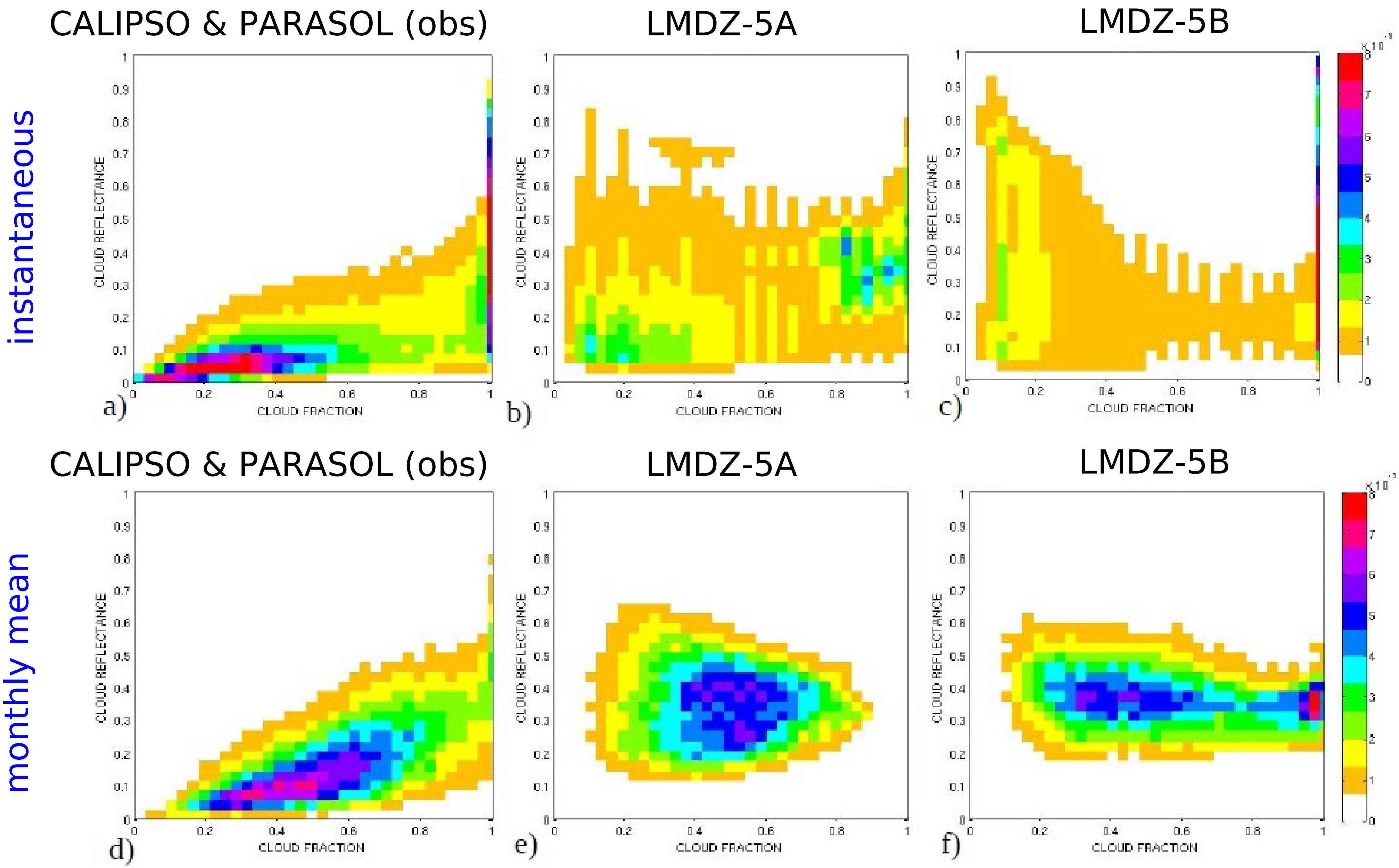


[Leahy et al., JGR, 2012]



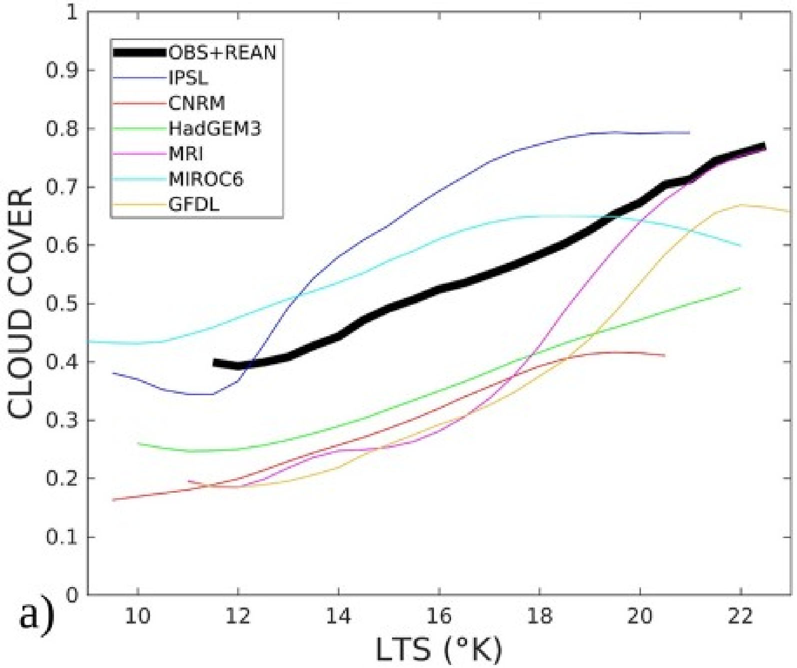
[Mieslinger et al., ACP, 2022]

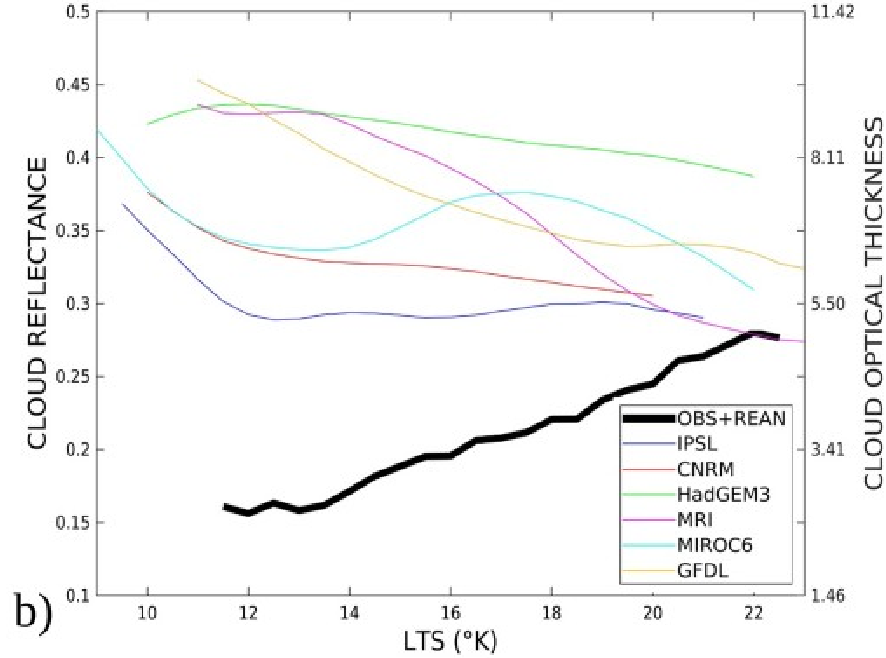
Comparing instantaneous vs monthly mean values

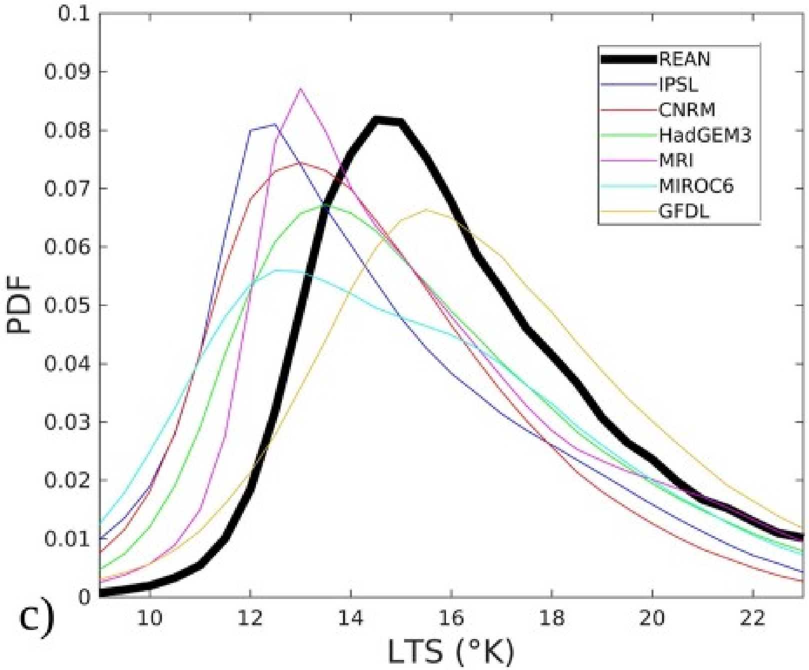


[Konsta et al., CDYN, 2016]

Variation with the environment



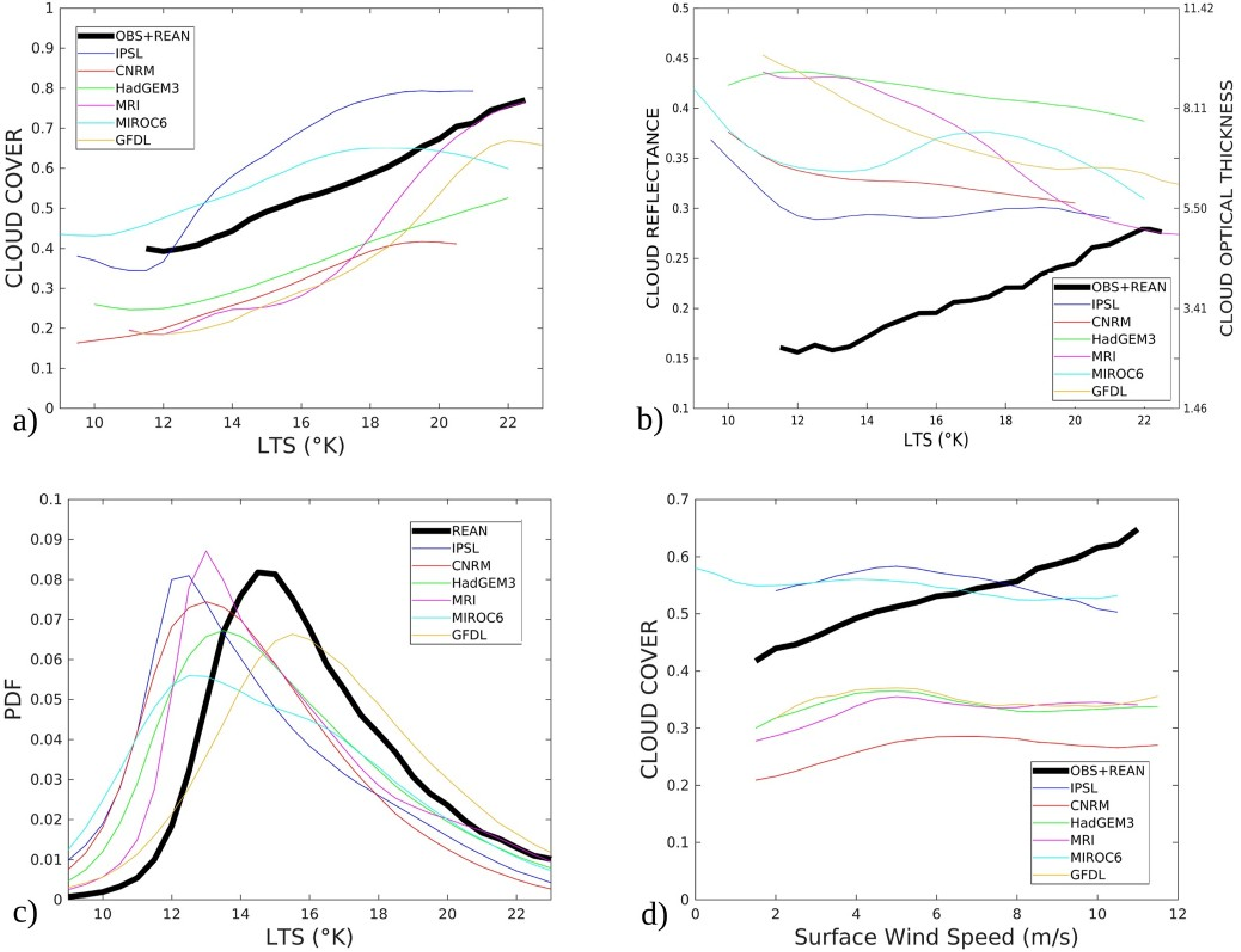




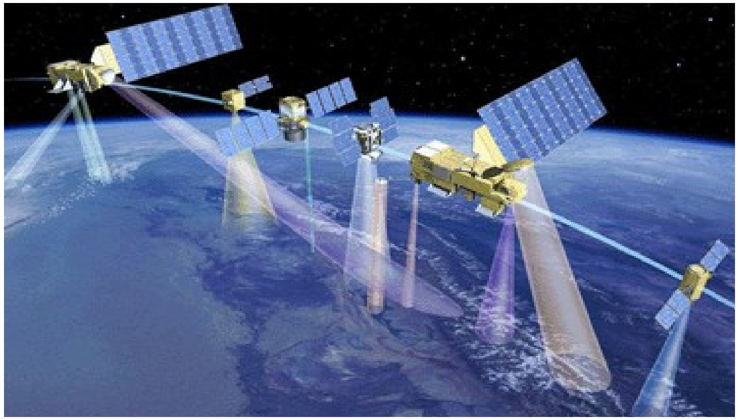
Low tropospheric stability

$$LTS = \frac{\theta(700\,hPa)}{\theta(surface)}$$

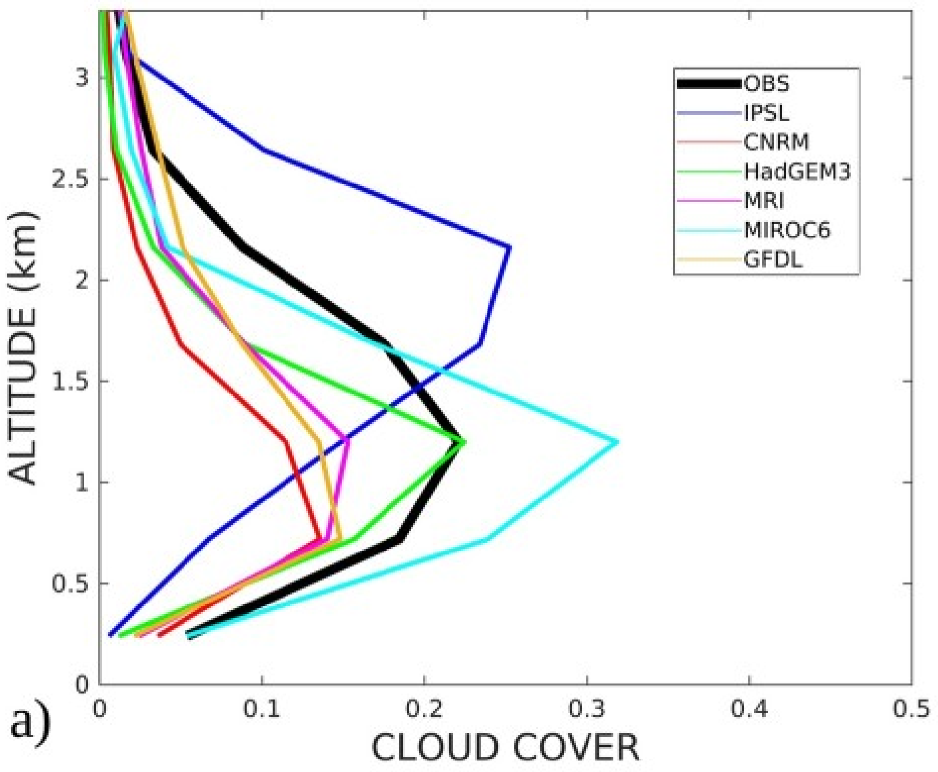
Variation with the environment



Vertical profile

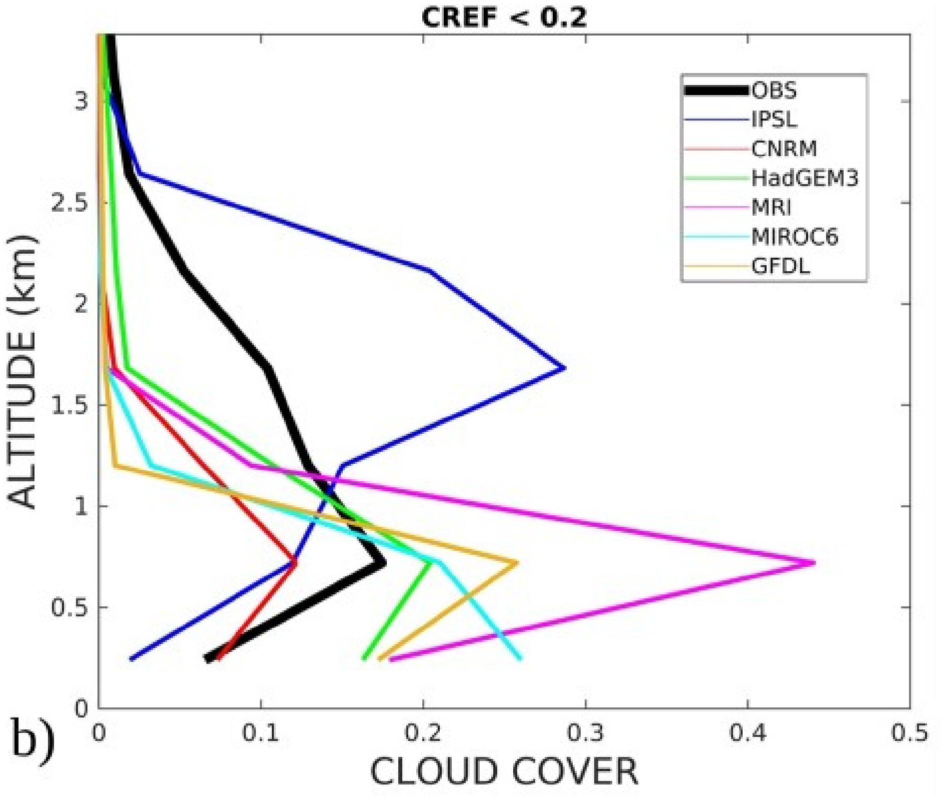


All low level clouds



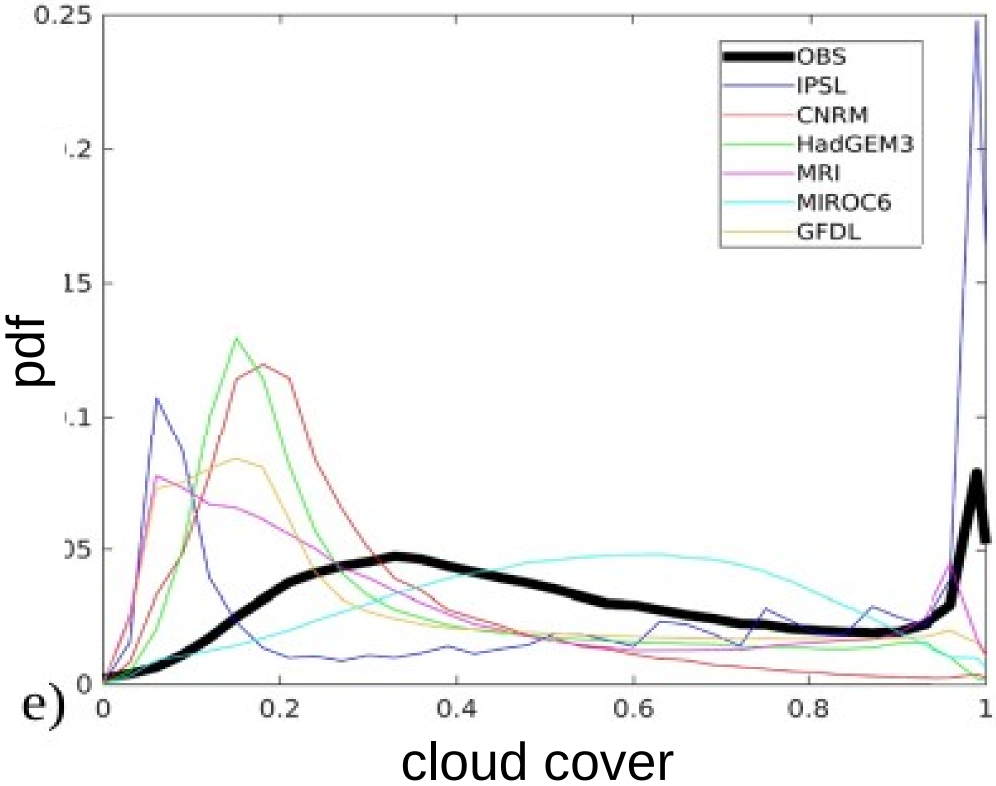
a)

Optically thin
low level clouds



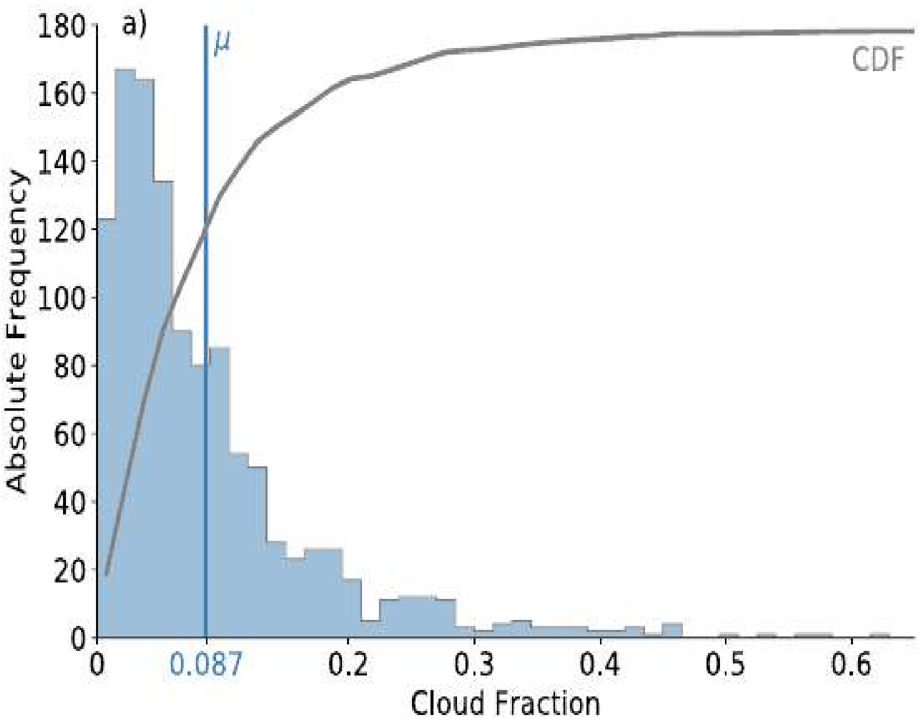
b)

Cover of low level clouds on a 2°x2°



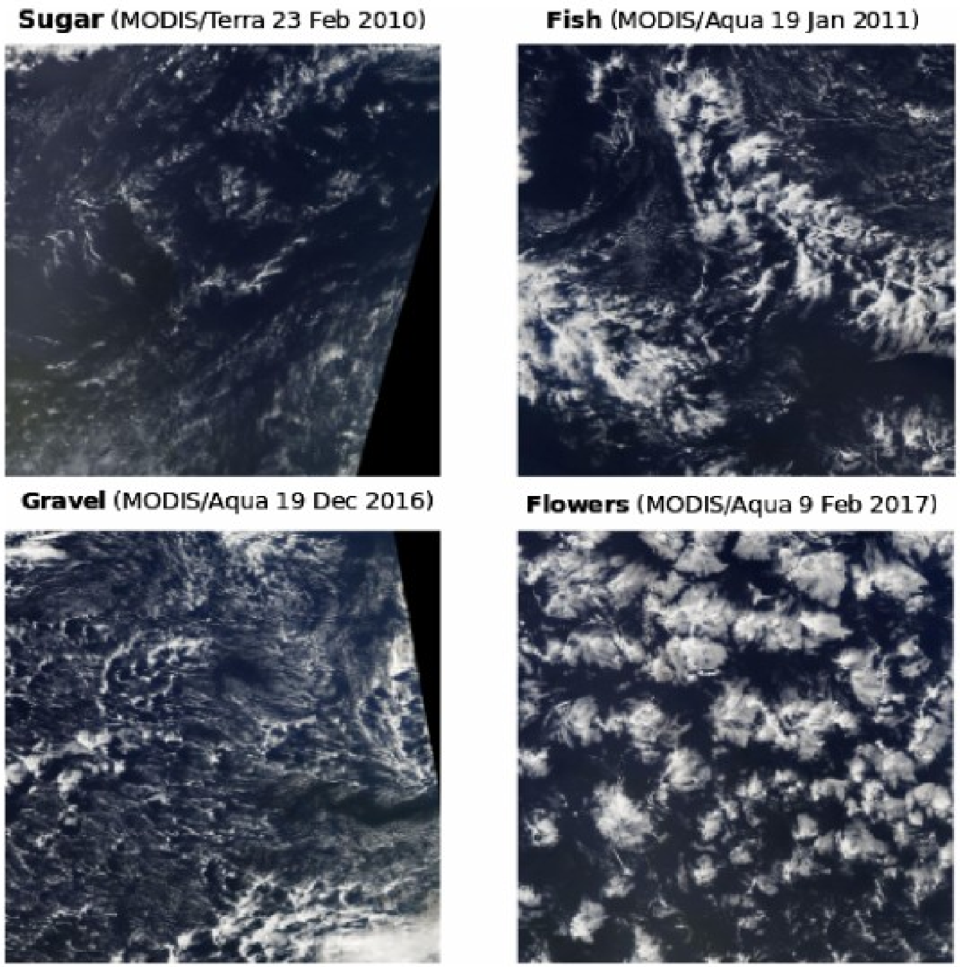
[Konsta et al., GRL, 2022]

Cover of cumulus clouds



[Mieslinger et al., GRL, 2019]

Small cumulus clouds are emblematic of trade wind regions, but are not the only ones present



10°x10°

[Bony et al., 2020]

- The probability of observing only cumulus clouds in a 2°x2° grid is low, they are almost always associated with some stratiform clouds
- Current climate models may be unable to simulate, in the same atmospheric column, a sufficient variety of low-level cloud types

Conclusion

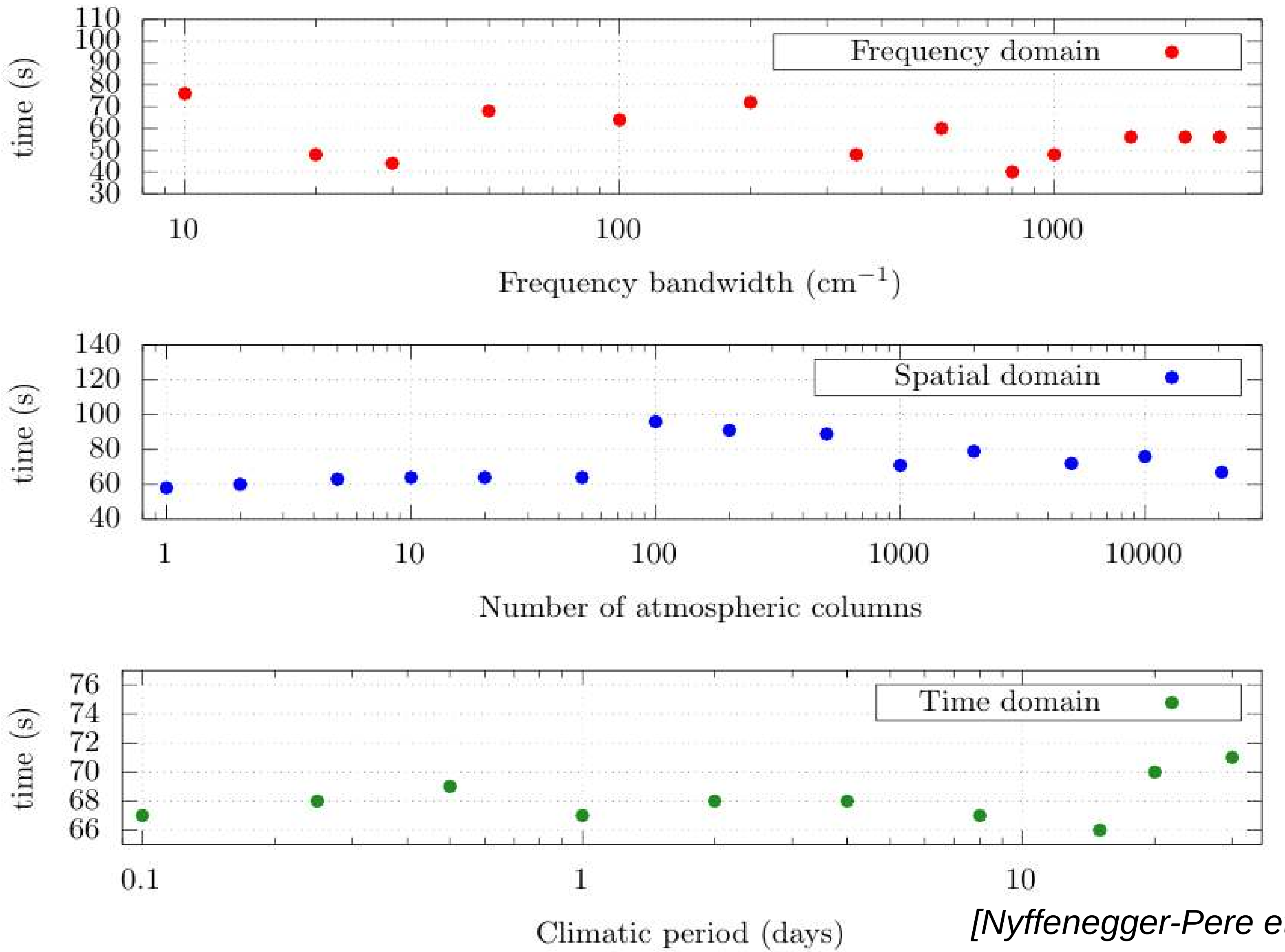
- **High frequency** (instantaneous to daily) measurements of clouds properties even on a coarse grid (1°x1°) allows
  - a deep analysis of how clouds properties varies with their environment
  - a meaningful comparison with models
- The clouds measurements don’t have to cover the whole grid cells, **sub-sampling is not an issue**

About sub and random sampling

- Context : development of a line-by-line Monte-Carlo radiative transfer model.
- For clear sky, 500 000 random samples are enough for random error lower than 0.1% on the TOA LW flux
  - 10 time steps on a 1°x1° grid
  - < 1/100 time steps on a km scale grid

About sub and random sampling

- Context : development of a line-by-line Monte-Carlo radiative transfer model.
- The number of samples is weakly dependent on the dimension of the integration space



[Nyffenegger-Pere et al., in prep.]